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INVESTIGATION OF THE EFFECT OF STRESS RELIEVING ON THE TOUGHNESS (CHARPY V), AND MECHANICAL PROPERTIES OF HY 100 STEEL TEE BEAMS HOT ROLLED, EXTRUDED AND COLD FORMED

LAB. PROJECT 9300-1, TECHNICAL MEMORANDUM 33

SR 007-01-01

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MATERIAL SCIENCES DIVISION

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Lab. Project 9300-1
Technical Memorandum #33

Administrative Information

Ref: (a) NAVAPLSCIENLAB Program Summary of 1 Nov. 1964, SR 007-01-01, Fabrication of High Strength Structural Steel Alloys.

FIGURES

1 - Typical Tee Beam Cross-Section
2 - Graphical Representation of Results

TABLES

1 - List of Materials and Thermal Treatments
2 - Static Tensile Data
3 - Charpy V-notch Data at minus 120 °F

1. In conjunction with the High Strength Steel Program of the U.S. Naval Applied Science Laboratory outlined in reference (a), an investigation of the effects of stress-relieving HY 100 hot rolled and extruded steel tee sections is being conducted. This report deals with the apparent detrimental effects on the toughness characteristics resulting from stress-relieving, as evaluated by Charpy V-notch properties. Yield strength characteristics were also investigated.

Background

2. The overall program is concerned with the development of information necessary for fabrication of high strength steel hulls for deep diving vehicles. In view of the fact that some structural assemblies incorporating tee beams might be stress-relieved, it was considered necessary to investigate the effects of stress-relieving.

Object

3. The object was to determine the effects of stress-relieving on the yield strength and toughness characteristics of hot rolled and extruded tee sections of HY 100 steel.

Material

4. Specimen material for the study was taken from the ends of ten (10) beams available at the Laboratory. These had been utilized in the investigation of structural behavior of the beams which will be reported under separate technical memoranda. Table I lists the form and thermal treatment associated with each beam. Beams referred to as curved were cold formed to the respective curvature after heat treatment but before stress relieving.

Specimen Preparation

5. Figure I shows a typical tee-beam cross-section indicating the positions from which the test material was obtained and the types of test specimens prepared. All specimens were made with the long dimension parallel with the direction of extrusion or rolling (longitudinal specimens). Charpy specimens were notched perpendicular to the beam surfaces. Laboratory stress-relieved specimens were machined from blocks which had been treated at the respective temperatures (1000 °F and 1050 °F), held for 72 hours, furnace cooled below 500°F and then air cooled. The tee beams stress-relieved at the Portsmouth Naval Shipyard were treated at 1025°F, held for 2 hours and furnace cooled.

Results

6. Tables 2 and 3 present data relative to the detailed results of tension and Charpy V-notch tests. Figure 2 is a graphical representation of the Charpy energy absorption characteristics (toughness), as received, and after stress relieving.

Analysis

7. General

a. Stress relieving markedly reduced the Charpy energy absorption properties (toughness) of straight and curved, extruded, and curved, hot rolled HY 100 beams. The straight hot rolled beam was affected to a lesser extent. A short summary table is presented below:

Average Charpy V-notch Energy (Ft. Lbs.) at -120°F

	Extruded		Hot Rolled	
	Straight	Curved	Straight	Curved
Before SR -	133	135	130	110
After SR -	45	65	110	67

b. Beams stress relieved for 2 hours (indicated by Portsmouth) or for 72 hours (processed at NASL), exhibited approximately the same degree of deterioration.

c. Stress relieving did not appreciably affect the yield strength or tensile properties of the flange. In view of the limited number of specimens tested from the web, further investigation seems warranted in order to further delineate any effects in this area of the beams resulting from stress relieving.

d. The properties reported are indicative of characteristics in the principal direction of fabrication (longitudinal). It is expected that transverse properties might not be as good.

8. Extruded Tees.

a. The pronounced deterioration in the toughness of extruded beams, resulting from stress relieving (as evaluated by Charpy V-notch properties) is shown in Figure 2. It will be noted that the straight beam (1E) shows a drop in average energy to below 40 ft. lbs. for 1000°F stress relief and below 60 ft. lbs. for 1050°F stress relief. Both of these values are below the specification requirement of 70 ft. lbs. minimum. The curved beams, with the exception of beam 5, show a similar loss in toughness.

b. It is believed that beam 5 was not effectively stress relieved. In this connection, it should be noted, that the structural behavior of beam 5 (to be reported in a future technical memorandum), was different from the other beams.

c. The average loss in toughness for the straight beam was 66 percent and for the curved beams 51 percent (#5 beam excluded).

9. Hot Rolled Tees - referring to Figure 2, it will observed that the straight beam (1R) showed a relatively small (average 20 ft. lbs.) loss in toughness as a result of stress relieving and the curved beams, a substantial loss in toughness (average 44 ft. lbs.). However, all averages were still above the specification requirement of 50 ft. lbs. minimum. The average loss in toughness (stress relieved) for the straight beam was 16 percent and for the curved beams 38 percent.

10. It should be noted that HY 80 and HY 100 steels are similar in composition and metallurgical characteristics. Accordingly, there is a good probability that some HY80 beams can show degradation on stress relief similar to that shown for the HY100 beams. This fact could only be established on the basis of a survey study, or a check of each lot of beams subjected to stress relief.

Conclusions

11. On the basis of the limited work reported herein, it is concluded that short or long time stress relieving of extruded and hot rolled HY 100 steel tee beams (in the range of 1000°F-1050°F) may significantly impair the toughness of the material.

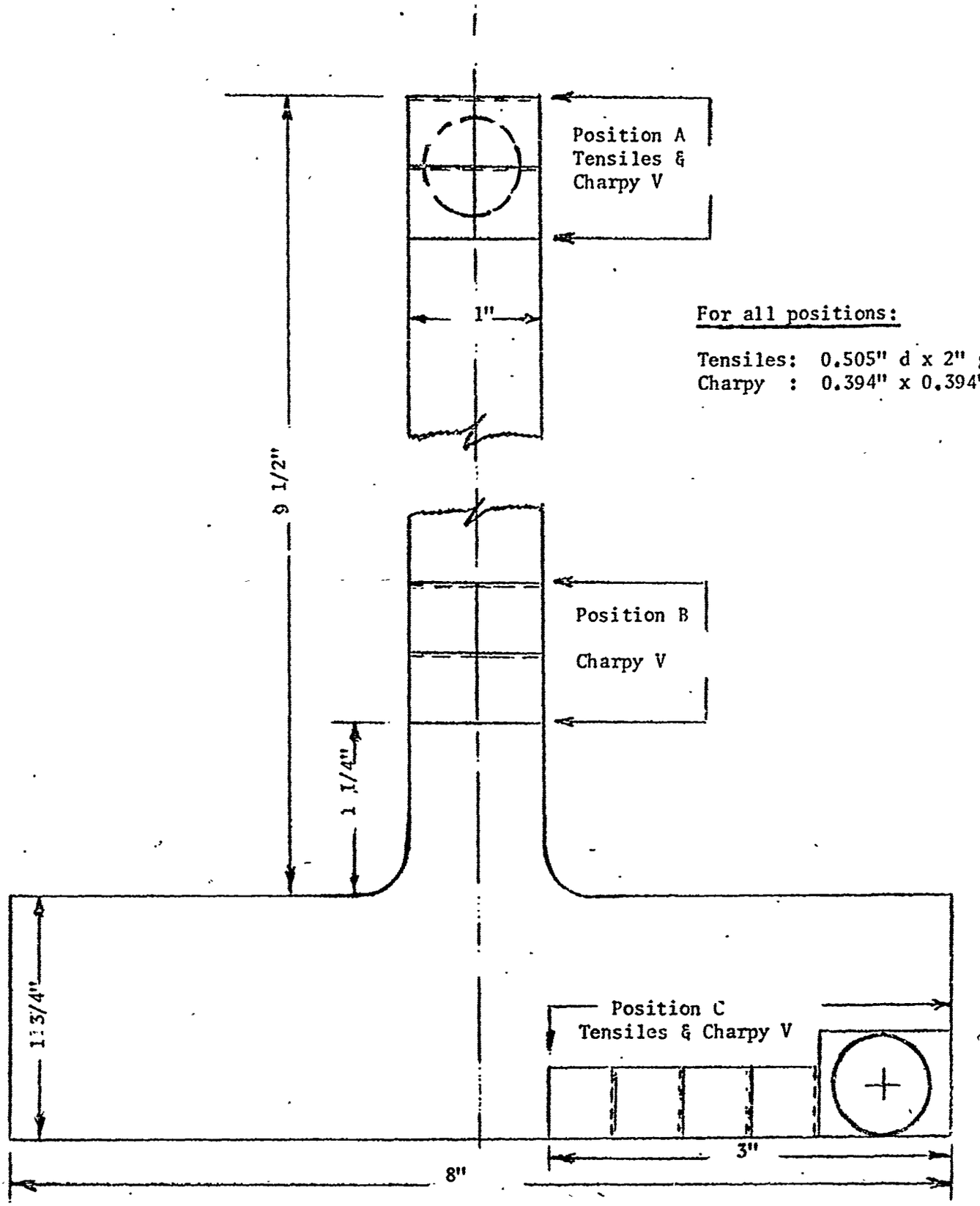
Recommendations

12. It is recommended that, the stress relieving of HY80 and HY100 steel tee beams, not be permitted, until a thermal treatment which does not cause toughness loss is demonstrated. In the interim, should the use of stress relieved material be required for a particular application, the toughness (Charpy V notch) of a sample representative of the particular stress relieved member (in its final worked form), should be determined. This procedure will selectively prevent the use of material of excessively low toughness.

Future Work

13. In view of the significant findings, a series of check tests on the subject beams is presently being conducted. Transverse properties (perpendicular to the main direction of rolling or extrusion) will also be investigated. In addition, a chemical analysis will also be conducted in order to determine whether marked differences in composition between the two types of beams (hot rolled and extruded) could have effected the behavior pattern on stress relieving.

14. Analogous work in the higher strength steels (HY 130 to HY 180 range) will be conducted when specimen material becomes available.



For all positions:

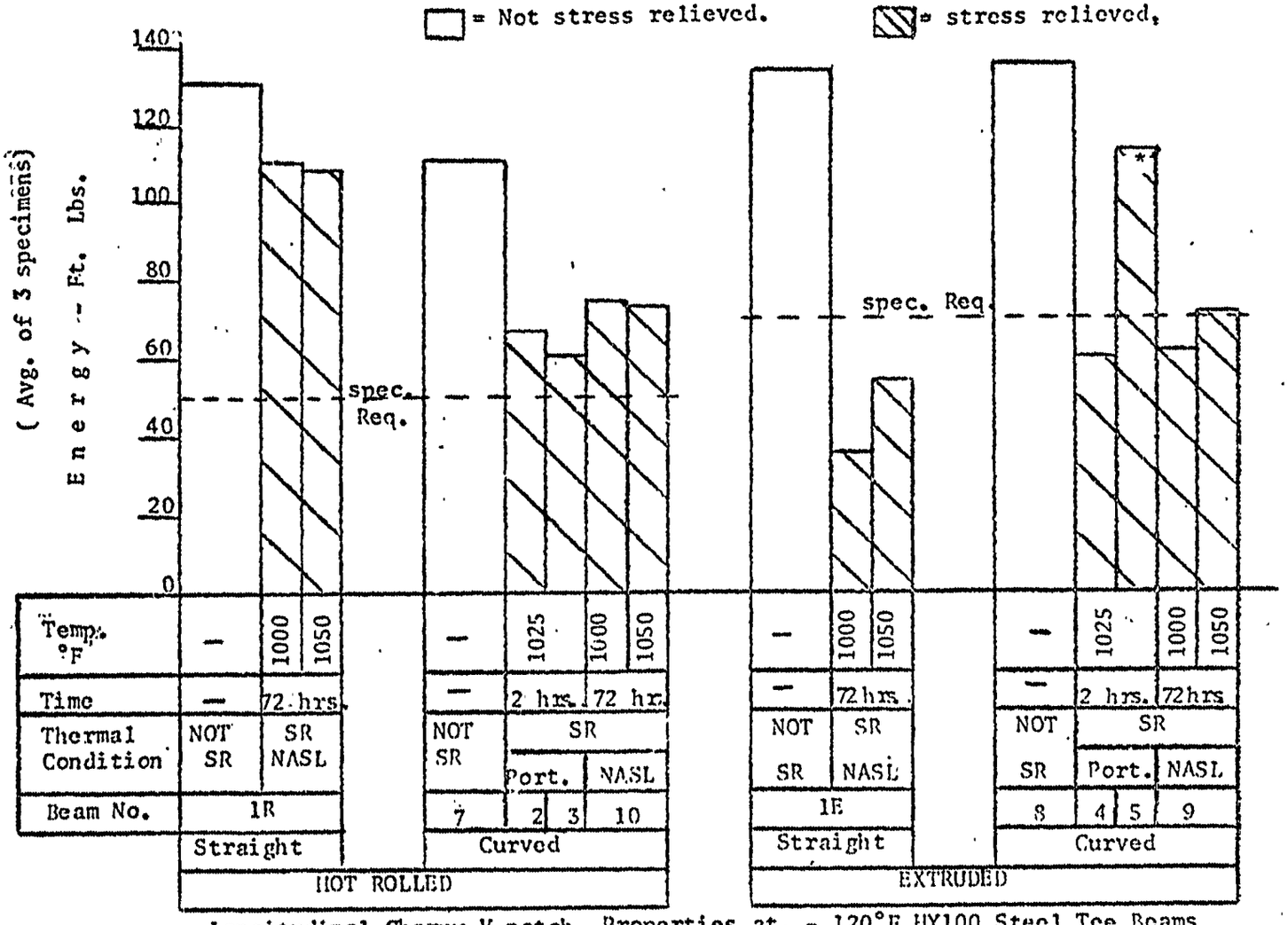
Tensiles: 0.505" d x 2" gage
Charpy : 0.394" x 0.394"x2.16"

Cross-section View of Typical HY 100 Tee Beam (not to scale)
Showing Locations from which Test Specimens Were Selected

Figure 1

Notes

curved=cold-bent after heat treat & prior to stress-relieving
all beams originally tempered at 1080°F after quenching
* = appears not to have been effectively stress relieved



Longitudinal Charpy V-notch Properties at, - 120°F HY100 Steel Tee Beams

Figure 2

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TABLE 1

HY100 Steel Tee Beams - As Received (numbers in boxes are Beam Codes)							
Hot Rolled				Extruded			
Straight		Curved		Straight		Curved	
Stress Relieved	NOT Stress Relieved	Stress Relieved	NOT Stress Relieved	Stress Relieved	NOT Stress Relieved	Stress Relieved	NOT Stress Relieved
None	1R	2 3	7 10	None	1E	4 5	8 9
Stress Relieving Treatments							
PORTSMOUTH 1025°F - 2 hrs. FC		NASL 1000°F - 72 hrs. FC		NASL 1050°F - 72 hrs. FC			
2,3,4,5		1R,10,1E,9		1R, 10, 1E, 9			

HY 100 Steel Tee Beams - As Received and Subjected to Stress Relieving Treatments as Indicated.

NOTE: Curved Beams - Web in Compression, Flange in Tension.

TABLE 2

			Position A (Web)				Position C (Flange)			
Beam Code and Condition			Yield Strength (.2%) KSI	Tensile Strength KSI	Elong. 2" %	Red. Area %	Yield Strength (.2%)	Tensile Strength KSI	Elong. 2" %	Red. Area %
HOT ROLLED	STRAIGHT	As Rec'd. 1R (NOT STRESS RELIEVED)	109	124	24	74	101	116	25	77
		Stress Relieved 1R (NASL-1000°F-72 hrs. FC)	108	125	24	73	102	116	25	75
		Stress Relieved 1R (NASL-1050°F-72 hrs. FC)	-	-	-	-	100	116	26	77
	CURVED	As Rec'd. 7 (NOT STRESS RELIEVED)	Not Obtained	113	23	74	100	112	25	76
		Stress Relieved 2 (Ports.-1025°F-2 hrs.FC)	98	116	22	72	109	117	25	73
		Stress Relieved 3 (Ports.-1025°F-2 hrs.FC)	100	116	22	72	114	126	20	72
		Stress Relieved 10 (NASL-1000°F-72 hrs. FC)	100	117	22	72	98	110	24	75
		Stress Relieved 10 (NASL-1050°F-72 hrs. FC)	-	-	-	-	95	110	25	76
EXTRUDED	STRAIGHT	As Rec'd. 1E (NOT STRESS RELIEVED)	102	113	27	77	106	116	22	75
		Stress Relieved 1E (NASL-1000°F-72 hrs. FC)	101	113	24	76	106	117	24	75
		Stress Relieved 1E (NASL-1050°F-72 hrs. FC)	-	-	-	-	106	117	23	75
	CURVED	As Rec'd. 8 (NOT STRESS RELIEVED)	Not Obtained	111	24	78	107	117	25	77
		Stress Relieved 4 (Ports.-1025°F-2 hrs.FC)	96	116	24	75	103	119	24	75
		Stress Relieved 5 (Ports.-1025°F-2 hrs.FC)	104	115	24	76	110	117	22	77
		Stress Relieved 9 (NASL-1000°F-72 hrs. FC)	95	110	24	77	106	115	23	76
		Stress Relieved 9 (NASL-1050°F-72 hrs. FC)	-	-	-	-	104	115	24	76

HY100 Steel Tee Beams - Tensile Properties - Hot Rolled and Extruded
Quenched and Tempered at 1080°F- Stress Relieved as Indicated

(NOTE - Beams 9 and 10 rec'd. NOT STRESS RELIEVED)

TABLE 3

		Beam Code and Condition		Position A (Web)	Position B (Web)	Position C (Flange)
HOT ROLLED	STRAIGHT	As Rec'd.	1R (NOT STRESS RELIEVED)	141, 120, 135, 112 (127)	129, 123, 124, 132 (127)	128, 143, 135, 140 (137)
		Stress Relieved	1R (NASL-1000°F-72 hrs. FC)	116, 100, 110, 111 (109)	104, 113, 104, 104 (106)	112, 105, 114, 128 (115)
			1R (NASL-1050°F-72 hrs. FC)	111, 99, 113, 108 (108)	113, 104, 100, 106 (106)	109, 112, 113, 111 (111)
	CURVED	As Rec'd.	7 (NOT STRESS RELIEVED)	105, 103, 109, 106 (106)	108, 103, 109, 108 (107)	122, 117, 123, 119 (120)
		Stress Relieved	2 (Ports.-1025°F-72 hrs. FC)	58, 76, 75, 78 (72)	71, 74, 52, 76 (68)	47, 63, 61, 64 (59)
			3 (" " " ")	70, 60, 78, 73 (70)	68, 74, 50, 52 (61)	46, 48, 51, 55 (50)
			10 (NASL-1000°F-72 hrs. ")	64, 77, 88, 71 (75)	80, 80, 65, 40 (66)	78, 90, 73, 86 (84)
			10 (" -1050°F- " ")	80, 72, 61, 74 (72)	71, 66, 77, 79 (73)	77, 93, 80, 54 (76)
EXTRUDED	STRAIGHT	As Rec'd.	1E (NOT STRESS RELIEVED)	152, 151, 137, 121 (135)	129, 134, 128, 140 (133)	129, 135, 136, 127 (132)
		Stress Relieved	1E (NASL-1000°F-72 hrs. FC)	81, 74, 41, 39 (59)	18, 21, 29, 20 (22)	28, 22, 23, 32 (26)
			1E (NASL-1050°F-72 hrs. FC)	95, 85, 89, 83 (88)	29, 28, 24, 40 (30)	43, 37, 50, 54 (46)
	CURVED	As Rec'd.	8 (NOT STRESS RELIEVED)	145, 134, 141, 141, (140)	135, 137, 145, 158 (144)	112, 125, 131, 118 (122)
		Stress Relieved	4 (Ports.-1025°F-2 hrs. FC)	69, 71, 56, 92, (72)	36, 33, 40, 37 (37)	58, 73, 93, 61 (71)
			5 (" " " ")	112, 129, 118, 110, (117)	129, 135, 122, 103 (122)	103, 104, 104, 90 (100)
			9 (NASL-1000°F-72 hrs. FC)	122, 106, 116, (115)	40, 48, 52, 77 (54)	25, 34, 25, 37 (30)
			9 (" 1050°F " ")	104, 113, 107, 109 (108)	61, 69, 57, (62)	43, 41, 41, 42 (42)

Charpy V-notch Properties at - 120°F
HY 100 Steel Tee Beams - Hot Rolled and Extruded - Quenched and Tempered at 1080°F - Stress Relieved as Indicated